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CASSELS

ANALYSIS OF THE CITY WATER (CLEVELAND)

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# REPORT

TO THE

Trustees of the Cleveland City Water Works,

OF THE

## ANALYSIS OF THE CITY WATER.

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BY

J. LANG CASSELS, M. D.

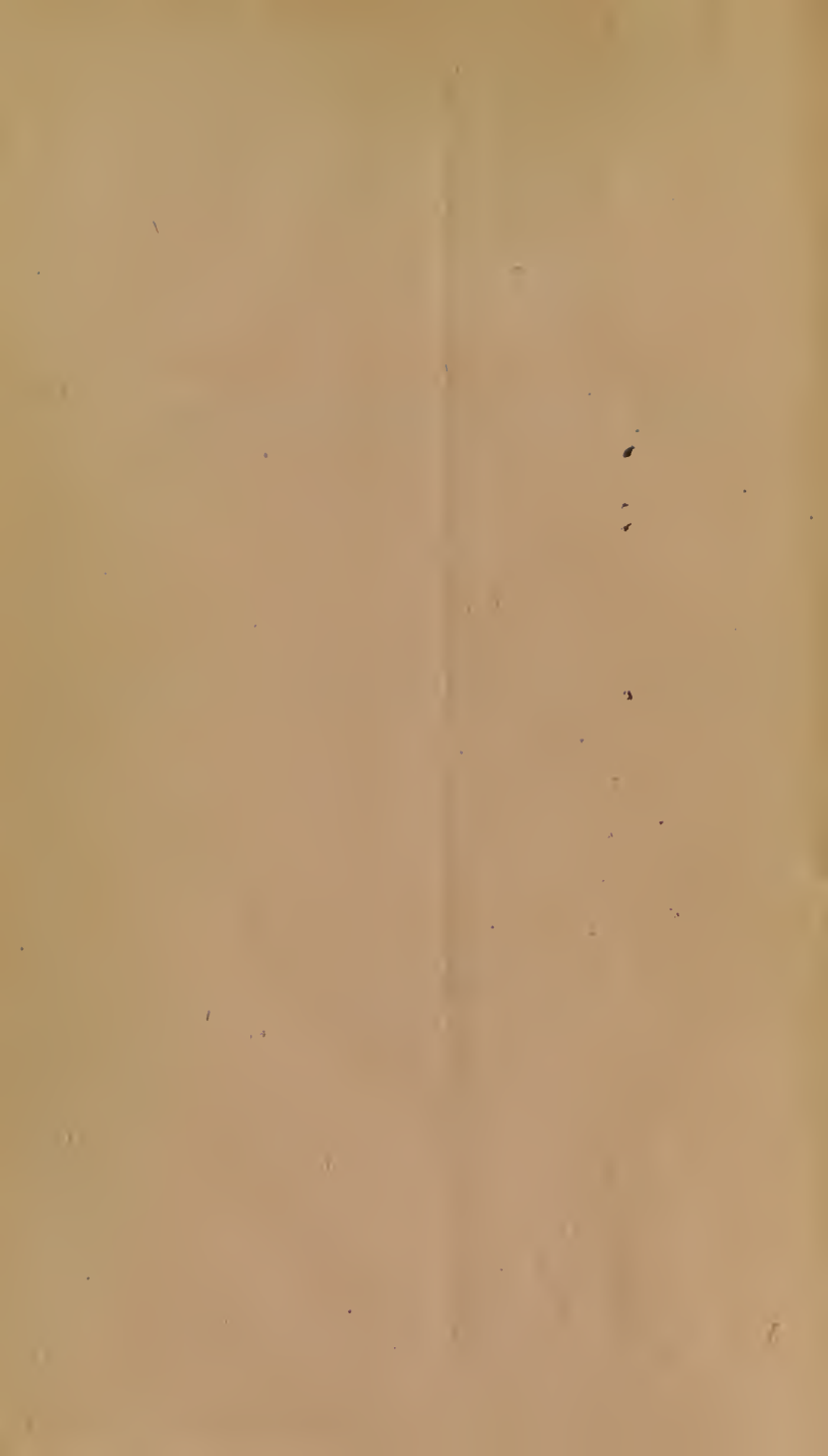
PROF. OF CHEMISTRY IN CLEVELAND MEDICAL COLLEGE.

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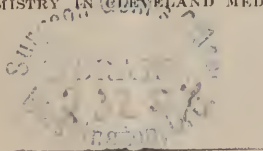
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# REPORT OF PROF. CASSELS.

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*To the Trustees of the Cleveland Water Works:*

GENTLEMEN:—Joseph Singer, Esq., Superintendent and Engineer of the City Water Works, in conformity with your instructions to him, engaged me to make a careful and thorough chemical analysis of the water with which the city is supplied. Also to institute a series of experiments to determine, as near as practicable, the effects of the water on lead and galvanized iron pipes, and its relative value for steam purposes.

As the result of these analyses and experiments, I respectfully present the following

## REPORT.

The water is taken from Lake Erie and forced into a reservoir situated on the high land on the west side of the Cuyahoga river—the inlet pipe being also on the west side of the mouth of the river—from which it is distributed to the different parts of the city.

The main distributing pipes are cast iron, the smaller ones sheet iron, coated with water-lime cement, while the connecting supply pipes are generally lead or iron, terminated in the dwellings with brass or composition stop-cocks. As it is required of all who take water to connect with the main street pipe by a certain number of feet of lead pipe of the same size of their supply pipe, the water of each consumer must necessarily pass through lead, whatever kind of supply pipe he may select, before it reaches the place of its consumption.

In order to arrive at the real chemical character of the water, and any changes which it may have undergone in the course of its distribution, the specimens submitted to examination were taken both from the lake and also from different localities in the city.

One specimen submitted to analysis, and other examinations, was taken from the "inlet tower," where the water enters the supply pipe leading to the force pump, to be thrown up to the reservoir. This inlet is one mile from the mouth of the Cuyahoga river, and four hundred and fifty feet from the shore. The water was carefully taken from a depth of four feet beneath the surface, by means of sinking clean earthen jugs, in such a manner as to exclude all surface water. This is designated as *No. 1* in the report.

*No. 2.* Was taken from the stop-cock in the office of the Weddell House Hotel, on the second floor of the building, where it is being constantly used for drinking purposes. This water is carried there from the street pipe through the usual lead connection, and iron and lead tubes, soldered together with common plumber's solder, and terminated with a composition stop-cock. The Weddell House is about a mile east from the reservoir.

*No. 3.* Was taken from a common hydrant, situated on the street level, at the Cleveland Medical College building, corner of Erie and St. Clair streets, about a mile and a half east of the reservoir. This hydrant has the general lead connection with the street pipe, the balance being iron pipe to the outlet, terminated by a common iron screw stop-cock.

*No. 4.* Was taken from the distributing pipe in my residence on Euclid avenue, corner of Case avenue, which is about three miles east of the reservoir. The water is conveyed from the street pipe to the house, through the connecting lead pipe, the balance, iron pipe; with some lead pipe connecting the outlet stop-cock with the iron pipe.

*No. 5.* Was obtained from the lake, about three thousand feet lakeward of the present inlet tower, from a depth of four feet beneath the surface.

This distance from the shore extends beyond the point where the turbid water produced by its erosive action on the shore, generally reaches. There, the water is usually clear and transparent. But it is very difficult to determine the exact bounds of this action and condition of the water; depending entirely on the state of the weather. At this distance, however, it is purer, a much larger part of the time, than at the present inlet. The reason for analyzing the water, from this point, was to determine its relative purity with the present supply—chemical and mechanical—with the object in view of considering the propriety of ultimately removing the supply inlet to this distance from the shore.

The physical properties of these different samples of water differed but little from each other, except that those taken from places the most distant from the reservoir, were the clearest; that from the inlet tower having the largest amount of sedimentary matters.

They all, except *No. 5*, when first obtained, were more or less opalescent, depositing a whitish sediment and becoming clear after remaining some time at rest. *No. 1* contained the most and *No. 4* the least of these matters, while *No. 5* was entirely free from them.

These sedimentary matters were collected and chemically examined. They were found to consist principally of clay, with a small percentage of silex, intermixed with a minute portion of vegetable matters.

The relative amount of these matters was determined, by passing a gallon of water, from each of the specified localities, through a double filter of the best Swedish filtering paper—the filters being carefully counterbalanced previous to filtration. The filters and their contained matters were dried at a

temperature of 212° F. till a constant weight was obtained, and weighed.

A gallon of	No. 1	contained	- - - -	5.652	grains.
"	No. 2	"	- - - -	1.604	"
"	No. 3	"	- - - -	1.485	"
"	No. 4	"	- - - -	0.802	"
"	No. 5	"	- - - -	nothing.	

Had these specimens been all collected at the same time, the result of the above examination would have been somewhat more satisfactory, in exhibiting the effects of the water's action on the lake shore, its powers of transporting into the lake these suspended matters, the time required for their deposition, and the amount deposited in the inlet pipe, the reservoir and the distributing pipes. But a close approximation to these points is obtained, for with the exception of No. 1, which was collected on the 19th of February, the others were all obtained within a short time of each other. The time of the collection of No. 1 readily accounts for the great amount of its sediment, being more than a true yearly average.

The result exhibits, in an interesting manner, the effects of quietude in the separation of these matters from the water, and the necessity of frequent cleaning of the main pipes, which, otherwise, would soon become unfit for their office. Happily the nature of these matters is such, that the main pipes can, at any time, be thoroughly cleaned by means of washing currents. In fact this is apparent to all who have ever witnessed the muddy state of the water which first issues from the street hydrants, when used for extinguishing fires, or for other purposes.

The amount of these matters must necessarily vary with the condition of the weather. When the lake is much agitated with storms, its erosive action on the shore is much increased, charging the returning waves with a larger quantity of silt, and carrying it further into the lake than during calms. This is the reason that the city supply varies so much in appear-

ance; for notwithstanding the great care with which the inlet pipe is guarded against the entrance of impure water, frequently the turbid water extends far beyond the inlet, rendering it absolutely impossible to obtain water free from these silty matters.

During these agitations of the water, a large quantity of the suspended matters are, of course, deposited in the inlet pipe before it reaches the pumps, and a still larger proportion of it finds a bed in the reservoir; but there is, nevertheless, enough that remains in the water until it reaches the supply pipes of the city, producing in it an unpleasant and milky appearance. The amount of these matters, however, even in the worst stages of the water, in this respect, is so trifling, that it can not be regarded as in the smallest degree deterrent to the animal economy; while the fastidious can readily remove them by simple mechanical filtration.

This unsightly turbidity may be entirely obviated by an extension of the inlet pipe to the distance from which specimen No. 5 was taken; although even here, during heavy storms, occasional silty visits might be expected. It might also, to a great extent, be modified by allowing the water to remain in the reservoir long enough to allow these matters to be deposited. But there are some very serious objections to this; the chief of which is, that it would give origin to an accumulation of those cryptogamic plants and animalculæ peculiar to stagnant water; which would be much more injurious to health than the small amount of inorganic matters that now occasionally mar the natural limpidity of the waters of Lake Erie.

Water is a solvent of very extensive powers, both of solids, liquids and gases. Hence when it falls on the earth in the form of rain or snow—which are very close approximations to pure water—it dissolves and becomes charged with a large proportion of all those organic and inorganic matters with which it comes in contact; and in its percolation through the



strata, it becomes more and more impregnated, till it issues in the form of springs. Hence the endless variety of natural waters, constituting hard and soft waters, mineral springs, &c., their characteristics depending on the chemical character of the rock formations, and subordinate strata through which they have passed. The geological character of a country, in which lakes and streams are situated, must therefore greatly modify the chemical constitution of their waters. In primitive regions, where the rocks, and their derivative soils, are chiefly granitic, the water is generally purer, and characterized as soft, containing the soluble salts of potash and soda in large proportion to its other constituents; while that of a limestone country—especially our western limestones, from the great quantity of carbonic acid derived from vegetable decomposition, rendering the limestone soluble by its presence—is designated as hard, having a large percentage of the salts of lime and magnesia, rendering it much less valuable for a great many purposes.

The shores of the upper end, or south-west portion of Lake Erie, together with its numerous islands, located in that region, are limestone. The natural downward current, sweeping through among these islands, must necessarily become more or less charged with lime and magnesia. Moreover, the large streams emptying into the lake, in this region, pass through the same limestone formation. This limestone, too, contains from twenty to forty-five per cent. of magnesia. Hence we may reasonably expect both lime and magnesia in the waters of Lake Erie, in the vicinity of Cleveland.

The degree of hardness, thus produced, sustains an interesting relation to the value of water for a great many purposes; especially in the generation of steam as a motor power, and many manufacturing operations—subjects in which Cleveland is largely interested.

The incrustations formed in the interior of steam boilers, so dangerous and destructive in their effects, are composed

mostly of the sulphate of lime and the carbonates of lime and magnesia. These carbonates are nearly insoluble in pure water, but are readily soluble in water containing an excess of carbonic acid gas. This gas, thus combined, is easily expelled by heat; hence water, holding these salts thus in solution, when boiled, loses its carbonic acid, and deposits them as insoluble carbonates. These, now mixing with the sparingly soluble sulphate of lime, adhere with great tenacity to the inside of the boiler.

The compactness of these incrustations is very much influenced by the relative proportion of the sulphate. The greater its quantity the more compact and hard the deposit. Where there is but little of this sulphate, the deposit is comparatively loose and muddy, and is readily removed by the process of "blowing out." The compact or loose nature of these incrustations, then, will very much depend on the relative proportions of these three substances, modified by the amount of heat used in the generation of the steam. The higher the temperature, the greater the deposit of the sulphate, even while falling far short of dryness, from evaporation. These deposits are also very much influenced by the presence of other matters; thus, some of the chlorides increase, while others diminish, the solubility of the sulphate of lime; thereby very much modifying the nature of the incrustation. The chloride of sodium (common salt) increases its solubility, while that of magnesium and calcium tend to diminish it.

It ought to be more generally known by those engaged in steam operations than it is, that heat alone possesses a great influence on the solubility of the sulphate of lime, and consequent modification of steam boiler deposits. Thus, it has been determined, by direct experiments, that above  $212^{\circ}$  F. its solubility rapidly diminishes with an increase of temperature. At  $255^{\circ}$  F. it is lessened about three-fourths, and it is entirely insoluble in water at  $300^{\circ}$  F. According to Bucholz, sulphate of lime requires 460 parts of water at  $60^{\circ}$  for solution. Thus

it is certainly very evident, that the chemical character of the substances held in solution in water, sustain an exceedingly interesting relation to the generation of steam, both in respect to the durability of the boilers, and the safety of those engaged in its operations.

To ascertain, by direct experiment, the effects of continued boiling, with the escape of the steam, on our city water, in reference to the formation of incrustations and their character, two quarts, taken from the hydrant near the college, were boiled down, in a suitable glass vessel, to about a quarter of its quantity. On cooling, no change could be observed, except a slight opacity; no deposit of any kind was thrown down. Three gallons were afterwards boiled down to about a pint, and allowed to cool. This gave a hard incrustation of a compact rusty colored calcareous character, adhering with great tenacity to the sides of the vessel.

From these experiments I infer, that long continued boiling, of large quantities of this water, in steam boilers, will give rise to incrustations of a highly deleterious character, unless prevented by frequent "blowing out." And perhaps among all the plans devised and recommended for the prevention and removal of these deposits, that of frequent and thorough clearing out the boilers, is the most reliable—whether the waters deposit a loose or compact sediment.

Sometimes it is desirable to ascertain by some simple, yet reliable process, the relative degree of hardness of natural waters; thereby indicating their value for steam and many other practical purposes. What is termed the "soap test" affords, when properly conducted, a very satisfactory approximation to the truth. This consists, in adding a small quantity of a saturated alcoholic solution of fine hard white soap, to distilled water; this will simply be changed to a delicate milky or opalescent color, and on agitation will give rise to frothy bubbles. The same treatment of a hard water, results in a curdy white precipitate, without bubbles or froth,—the



harder the water the greater the deposit of curdy matters and *vice versa*.

By the soap test the waters of Lake Erie, at Cleveland, may be ranked as hard water, but in a low degree. Thus if pure distilled water is taken as one, and very decidedly hard water as ten, then this water would rank as two. As a base of comparison, the Croton water of New York would, by this scale, be classed as one and a half.

In the following analyses the United States standard gallon was adopted; and the solid matters contained in the water are reduced to the number of grains in the gallon. I have preferred this arrangement because it is, at present, generally used in this country, in weighing and measuring other solids and liquids, and consequently better understood by those most interested in such results.

The United States gallon contains 231 cubic inches, or 58318 grains of pure water, at a temperature of 60° F., and Bar. 30 inches. Great care was taken in measuring the water, and having it at the proper temperature during its measurement.

The method pursued, in the varied operations of determining the relative amount, character and chemical relations, of the foreign matters held in solution in the water, is mainly that of Fresenius, as given in the last edition of his valuable work on quantitative analysis. The water was all carefully filtered previous to concentration; by which means every thing was removed that was simply mechanically mixed or suspended in it.

Perhaps it may be proper to state, in this connection, that the different substances found in the water were not separated and weighed in the characters in which they are expressed in the detailed formulæ of the report, although they doubtless are so arranged in the water. With the exception of the silica they were all obtained and weighed in some of their combinations with other substances, whose numerical relations

are well established, and their weight determined by calculations, based on the relations which the elements of a compound sustain to each other. This method, always adopted by analytical chemists, when properly carried out, affords the most satisfactory results. By it the weight of a substance can be ascertained which is infinitely too minute to be separated and determined by the balance in an uncombined state.

Without pretending to enter into a very minute description of all the minutiae of the processes followed out in the detailed analyses, it may, however, be more satisfactory to state the leading points in these processes.

1st. The *silica*, *oxide of iron*, *alumina*, *lime*, and *magnesia*, were determined by acidulating a gallon of the water with chlorohydric acid, and evaporating to dryness—first in a porcelain and subsequently in a platinum vessel. This was dissolved in chlorohydric acid, boiled in distilled water and filtered, to remove the silica; which was weighed, after drying and ignition. The *oxide of iron* and *alumina* were precipitated from the filtrate by ammonia, and removed by filtration. The *alumina* was separated from the iron by potash and carbonate of ammonia, and weighed separately after drying and ignition. The *lime* was thrown down from the filtrate by oxalate of ammonia and liquid ammonia, while hot; and after remaining two days, to settle, it was repeatedly washed with hot distilled water, redissolved by chlorohydric acid, and again precipitated with ammonia, filtered, dried, ignited and weighed as a *carbonate*. The filtrate was concentrated by evaporation and the *magnesia* separated by phosphate of soda and ammonia, and weighed, after ignition, as the *phosphate of magnesia*.

2d. The *sulphuric acid* was obtained as the *sulphate of baryta*, by acidulating a gallon of the water with chlorohydric acid, concentrating it, by slow evaporation, to about half a pint, and adding, while boiling hot, the chloride of barium;

and the *sulphuric acid* calculated from the weight of the washed, dried and ignited *sulphate of baryta*.

3D. The *chlorine* was determined from the weighed *chloride of silver*, obtained by rendering a gallon of the water distinctly alkaline with the carbonate of soda, evaporating it to about half a pint, acidulating with nitric acid, and adding a solution of the nitrate of silver.

4TH. The presence and amount of *potash* and *soda* were ascertained by slowly evaporating, by a moderate heat, two gallons of the water to about half a pint, and carefully filtering. The filtrate was treated with chloride of barium, and again filtered, and the filtrate boiled with milk of lime, and after cooling, again filtered. This filtrate was boiled with carbonate of ammonia and liquid ammonia, to which was added a little oxalate of ammonia, by which all the lime might be entirely removed. After filtration, it was evaporated to dryness, and ignited in a platinum vessel, to expel all traces of ammonia. The chlorides of potassium and sodium thus obtained were separated and determined in the usual way by the bichloride of platinum.

5TH. The amount of *free carbonic acid* was determined by driving it off from a quart of the water by heat, and passing it into lime-water, and subsequently calculating the amount from the resulting carbonate of lime.

6TH. *Phosphates and Nitrates*.—Neither of these could be detected by the most delicate and reliable tests, in any of the specimens, even when largely concentrated,—for which purpose two gallons of the water was slowly and carefully evaporated down to half a pint.

7TH. *Organic Matters*.—To ascertain the relative amount of organic matters associated with the inorganic, a gallon of the water, after filtration, was evaporated to dryness, first in a porcelain basin and finished in a counterpoised platinum vessel at a temperature of 212° F., and kept at that temperature until a constant weight was obtained, and weighed. This gave the weight of both the organic and inorganic substances.

After thorough ignition, which burned off all the organic matters, it was again weighed; the loss indicating the weight of the organic matters. In order to make this result perfectly reliable, the inorganic matters thus obtained were moistened with a solution of the carbonate of ammonia and dried at 250° F., and repeated until a constant weight was obtained, and again ignited, and weighed.

III. *Distribution of Acids and Bases.*—In this the common method was adopted. The principle, that at present, guides chemists in the hypothetical associations of the acids and bases, found in natural waters, is to assume that the combination of the bases and acids is governed by their respective affinities; *i. e.*, the strongest acids are assumed to be combined with the strongest bases, &c. Although the solubility of these salts must necessarily influence these affinities, yet in the distribution adopted in this report, this is entirely disregarded. On this principle chlorine was given first to potassium and then to sodium. In the distribution of sulphuric acid the same rule was observed; first to potassa, then soda and lime. The residue of the lime and the magnesia were reckoned as simple carbonates.

Carrying out in detail this arrangement of substances found in the water, by the processes thus cursorily described, a gallon of each of the different specimens of water acted upon, was found to contain as follows,—in grains:

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
Chloride of potassium,.....	0.080	0.080	0.080	0.078	0.086
Chloride of sodium,.....	0.190	0.180	0.180	0.185	0.190
Sulphate of potassa,.....	0.125	0.025	0.025	0.086	0.090
Sulphate of soda,.....	0.017	0.025	0.030	0.040	0.185
Sulphate of lime,.....	2.575	2.475	2.470	2.470	2.470
Carbonate of lime,.....	1.175	1.150	1.160	1.160	1.165
Carbonate of magnesia,.....	0.650	0.520	0.500	0.480	0.488
Peroxide of iron,.....	0.021	0.025	0.030	0.040	0.038
Alumina,.....	0.057	0.100	0.060	0.060	0.058
Silica,.....	0.080	0.070	0.100	0.032	0.030
Organic matters,.....	1.800	1.750	1.740	1.710	0.640
Total,.....	6.800	6.400	6.375	6.371	5.440
Free carbonic acid, in cubic inches,.....	6.115	6.000	5.375	5.675	6.400

A comparative estimate of the character of our city water, may be made from the following table of the solid matters

existing in a United States gallon of the water used in other cities. It has not been deemed necessary to insert here, for this purpose, the full detail of the different substances found in these waters, but simply the number of grains of solid matters in the gallon.

The Croton river water in New York contains.....	6 6600
The Schuylkill river water in Philadelphia contains.....	4 2600
The water of Long pond of Boston contains.....	1 2220
The water of the Ohio river, used in Cincinnati contains.....	6 7361
That of the Detroit river, used in Detroit contains.....	6 3343
That of the Onondaga Hill spring, used in Syracuse contains.....	40 9000
The water of Lake Erie, used in Cleveland contains.....	6 4865
That of Lake Erie a mile and a half from the shore at Cleveland.....	5 4403
That of Loch Katrine, used in Glasgow contains.....	2 1500
That of the river Dee, used in Aberdeen.....	4 0000

In its sanitary relations, there is no subject connected with the supplying a city with water, next to its abundance and purity, in which the citizens are more generally and directly interested, than that of the mode of its distribution, in order to maintain its original purity. And here the subject of the action of these waters on lead, sustains an exceedingly important relation; because this metal is so generally used, and in so many different ways, in connection with water works, on account of the ease with which it is adapted to the various contrivances for its conveyance and distribution; and because it is more or less soluble in all waters, in some of its chemical relations; while its effects on the human organism, thus introduced, are slow and insidious, but at the same time so certainly deleterious.

As early as the time of Augustus Cæsar the Roman architects condemned the use of lead for either conveying or holding water, to be used in culinary operations, on account of compounds being formed which were regarded as baneful to the human system. Galen reprobated, in the strongest terms, the use of lead pipes for carrying water. He said, it rendered the water unsightly and muddy, and those who used it were subject to attacks of the severest form of colic, and the most uncontrollable and fatal forms of dysentery.

Since then to the present time physicians and chemists have given this subject a vast amount of both chemical and medi-



cal attention, without arriving at any definitely fixed conclusion. There are several important points, however, on which nearly all agree, as being fixed and determined scientific truths. Thus most medical men agree as to the manner of action, on the human system, of the different compounds of lead, and their peculiar poisonous effects. Little discrepancy obtains among them, on their accumulative powers. That is, it is generally acceded, that the salts of lead may be taken into the system, in very minute quantities and for a length of time, lie dormant, without any unpleasant effects being manifested, but suddenly become developed with great virulence and even fatal effects,—without increasing the quantity.

Chemists are generally of the opinion, that lead is much more readily acted upon by some waters than by others; and the purer the water the greater and more rapid this action. They also generally suppose, that the presence of certain soluble salts in the water, prevents the action of the water on the lead, from their assistance in forming a coat of an insoluble salt of lead on its surface. Some eminent chemists, however, maintain that even then, enough of these lead compounds are produced to prove hurtful to those who use the water. And moreover, that some persons are much more susceptible to this lead action than others.

It is also generally conceded by chemists that those waters deemed the most desirable for city purposes are the most subject to lead contamination; *i. e.*, the purer the water the greater its effects on lead.

Without taking any part in this interesting controversy, I have deemed it only necessary to cite a few experiments made by Prof. Christison on different waters, and his conclusions drawn therefrom; with those I have made with our city water.

Prof. Christison says: “Distilled water deprived of its gases by ebullition, and excluded from contact with the air, has no action whatever on lead. If the water, however, contains the customary gases, in solution, the surface of the metal, freshly polished, becomes quickly dull and white. But if the surface

of the water be not at the same time exposed to the air, the action soon comes to a close. When the air, on the other hand, is allowed free access to the water, a white powder appears in a few minutes on and around the lead; and this goes on increasing till in the course of a few days there is found a large quantity of white matter, which partly floats in the water, but is chiefly deposited on the bottom of the vessels. If the air is deprived of its carbonic acid, this white substance is the hydrated oxide. But if the surface of the water is exposed to the open air, a pale grayish powder is produced, which is the carbonate of lead."

He adds: "The formation of the carbonate takes place with considerable rapidity." He found that polished lead rods weighing 340 grains lost two grains and a half in eight days, when placed in twelve ounces of distilled water, in a shallow glass basin, loosely covered to exclude the dust. He also obtained 120 grains from an ounce of lead kept in twenty-four ounces of distilled water, for twenty months.

During these corrosions he ascertained that some of the lead is held in solution, and he is of the opinion that the lead is first oxidized and subsequently becomes the carbonate.

It is generally conceded by chemists, that this corroding action on lead is very much modified by the presence of certain salts in the water; but to what extent this protective power exists, and to what extent it can confidently be relied upon, are still undecided questions. Gayton Morreau was probably the first whose attention was directed to this subject, from observing that while distilled water acted on lead, no such changes were produced by certain natural waters. On further testing, he found that those springs, and river waters, containing sulphate of lime, and chloride of sodium, corroded lead but little, but increased its weight. From a series of experiments he concluded that water containing a five hundredth of sulphate of lime possessed no corrosive action whatever.

Christison, from his experiments, concludes that this protective power varies with different salts; the most effectual

being the sulphate of lime, in conjunction with chloride of sodium. He says: "After a few weeks exposure of lead to waters containing these salts, it acquires a thin film, over its surface, which wholly guards against any further corrosion. In all such protecting solutions the lead gains weight for some weeks; but at length it ceases to undergo further change. This coating when once formed adheres with great firmness. Moreover, the most careful examination can not detect any lead, either dissolved in the water, or floating in it, or united with the insoluble matters left on the side of the glass by evaporation. In short the preservation of the lead from corrosion, and of the water from impregnation with lead, is complete."

Although these experiments were made with the utmost care, by that eminently reliable chemist, yet it must be acknowledged, that the subject is not free from doubts, when applied practically on a large scale. Moreover, it is well known that when lead, either in sheets or pipes, has been for some time exposed to the action of air and water, it assumes a semicrystalline texture, rendering its whole substance easily permeable to their united action, causing chemical changes which could not be obtained in laboratory experiments.

It must be a somewhat difficult task to determine with certainty, even by adopting Christison's rule, that there are protective salts in our natural waters, in the proper quantities to prevent entirely their action on lead. And especially must this be the case, when these pipes are in metallic connection with iron or brass, as they generally are, in distributing pipes, which, by their electrical relations, must necessarily modify this action.

From the subjoined statement of the late Dr. James R. Chilton, the well known analytical chemist, of New York, it appears that the Croton water of that city does not act as a protective: "Some months after the introduction of the Croton water into our city, my attention was called to investigate its action upon the lead pipes which were to carry it into dwelling houses, &c. In several instances I detected lead



in the water which had stood in lead pipes over night, in situations where free use was made of the water during the day, and in some instances this daily use had continued several weeks. I have also found notable quantities of lead in the Croton water which I drew from a lead pipe in the third story of a house, at least a year after the pipes had been in the house. This water had probably remained in the pipes for more than a week. Subsequent to this, I made a series of experiments with a view to determine the action of Croton water upon pipes made of pure lead, and of alloys of tin and lead, and also of those made of lead coated with pure tin. These pipes, of some thirty or forty feet in length, were filled with water brought in a cask from the Croton river. The water was displaced from the pipes by admitting a fresh supply at intervals of a day or two, for three weeks; and that which escaped was tested each time. That which passed through the lead pipe always contained lead; while that from the pipe made from the alloy of tin and lead, as also that from the pipe coated with tin, inside and outside, did not contain a particle of lead, but for the first few days yielded a trace of tin." To which he adds: "It is possible that the water in passing rapidly through a lead pipe, of moderate length, in constant use, may not become so impregnated with lead as to be injurious to health." It may be proper to add that the pipes referred to by Dr. Chilton had been constantly used for several months.

Dr. Dana found lead in the water of the Merrimae river, after passing through lead pipes, in the city of Lowell, Mass. Dr. Hayes has detected lead in the waters of Jamaica pond, drawn from the lead pipes in Boston, which had been in use several years as service pipes. This water ought to act as a protective, in an eminent degree, as it contains the reputed protective salts in large quantities.

It may safely be stated that all river and lake waters manifest an action more or less on lead—the purer the water the greater the action, all other things being equal. This action may possibly diminish with time, but it is highly probable

that it never entirely ceases as long as the pipes are in use, for the purpose of conveying the water.

The following examinations and experiments were made on the Lake Erie water distributed in our city, in reference to its action on lead. A gallon of the water, taken from the Weddell House office, was evaporated at a temperature of  $180^{\circ}$  F. to four ounces, and tested for lead. Two ounces of this had a stream of sulphydric acid gas passed into it. The other two ounces were filtered, acidulated with nitric acid, and evaporated to dryness. After expelling the excess of nitric acid by heat, it was dissolved in distilled water, and divided into three equal parts; sulphydric acid gas was passed into one, solution of iodide of potassium into another, and the chromate of potash into the third. Neither of these tests gave indications of lead. A similar examination, with the same result, was made on water taken from the second story of my residence on Euclid avenue. This was drawn in the morning, when the water had lain in the pipes ten or twelve hours. In other examinations, made at different times, and on water collected at different localities, in the city, I have in every instance failed to detect lead.

In order to determine the effects of lead on our city water, when allowed to remain in contact with it, three bars of common lead, thoroughly cleaned and polished, were placed in three glass vessels filled with water. These bars weighed respectively 154.5 grains, 160. grains and 170.5 grains. Each vessel contained four measured ounces of water, taken from the hydrant near Cleveland Medical College. The vessels were loosely covered to exclude dust. Two hours after immersion they all lost their shining white lustre and became of a dull bluish hue. On the fifth day, they all presented a dull gray color; when No. 1 was taken out, dried with bibulous paper and weighed; it had not changed in weight, and no lead could be detected in the water. On the seventh day No. 2 was weighed; it had gained 0.015 grains and a mere trace of lead was indicated in the water. On the tenth day No. 3. had scarcely changed in appearance, and when weighed it had lost 0.025 grains in weight, and the water

gave strong evidence of the presence of lead. Immediately after weighing this bar, without cleaning, it was placed in the vessel with fresh water from the same hydrant, and remained in it for eighteen days, when it was found to have neither changed in color, nor weight, and no traces of lead could be discovered in the water.

520.5 grains of common lead pipe, were soldered to a brass stop-cock and immersed in half a pint of water taken from the same hydrant. This pipe was not cleaned except to remove, by washing, any loose matters that might have been attached to it. Two days after, a portion of the water was tested for lead, but no indications of it could be found. Twelve days after, a portion of the water was again tested, when very slight indications of lead were observed. After remaining in the water three weeks another portion of it was tested, with a result almost identical with the last examination. In four weeks from the time of its being first placed in the water, it was dried and weighed, when it had lost 0.752 grains, and the water was found to be highly charged with lead.

From these experiments, and others of a similar character, followed by similar results, it is very certain that the city water will act on lead under certain circumstances, while its protective action is of a very doubtful character, and can not with much certainty be relied on. But its corrosive action is of exceedingly slow progress, requiring a much longer time of contact, to produce the same effect, than either the Croton of New York, the Schuylkill of Philadelphia, or the Cochituate of Boston. And, it may be added, that in the general arrangement of the distributing pipes adopted in Cleveland, little danger need be apprehended from the presence of lead. Nevertheless, the less lead pipe used, the less liability to the deleterious effects of its corrosive action; and it ought to be generally known, that some constitutions are extremely susceptible to the baneful effects of the salts of

lead, requiring but very minute quantities to produce the most grave consequences, and there are no means of determining the amount necessary to produce these sad effects, short of the most painful and hazardous experiments.

A series of experiments were also made, to determine, as near as possible, the action of the water on galvanized iron. The object of these, was to ascertain what might be the result in using galvanized iron pipes to convey the water from the main pipe to the dwellings of the consumers. It is well known that galvanized iron is simple iron coated with zinc; which from their electrical relations protects the iron from corrosion. This protection of the iron, however, is at the expense of the zinc, which is thus rendered more easily acted upon by solvent agents than it would be if not thus associated with the iron.

Although the salts of zinc are not generally ranked among the more virulent metallic poisons, yet they are undoubtedly exceedingly injurious to the human constitution. Their continued use, even in minute quantities, is followed by a series of ailments which may not be immediately fatal, but ultimately result in very serious sequences.

These effects of zinc were demonstrated to a sad degree, a few years ago, in Lancashire, England, from the use of zinc milk pans in butter making. It was found that the cream separated more readily in zinc than in tin pans, as the zinc combined with the acid of the milk as soon as formed. But this salt of zinc found its way into the butter, and almost every person who used it was taken sick of a disease of a peculiar type. Many of these cases proved fatal. An analysis of the butter revealed the cause of this peculiar and wide spread sickness. The public authorities, when the cause was ascertained, interfered and prohibited the use of zinc milk pans under a severe penalty.

The zinc commonly used for galvanizing iron is of a very inferior quality. A large proportion of it being old zinc;

which of course is much mixed with other metals, such as lead, antimony, brass, &c., all of which contribute largely to the formation of soluble salts in the water. But even new zinc is seldom free from these impurities. Hence even the best of galvanized iron pipes, met with in market, must necessarily endanger the formation of soluble salts, both of zinc and other metals, which may be neither safe nor pleasant to the consumer of the water conveyed through them.

In order to test this matter by direct experiment, 1211.95 grains of new galvanized iron chain, such as that used in the common chain pump, were put into a pint of the water taken from the hydrant near the College, in a glass beaker, loosely covered to exclude dust. In twenty-four hours the water was of a bluish white color and tasted distinctly of the salts of zinc. In three days a whitish sediment was observed collecting on the zinc, which was easily detached by agitation. After remaining a week in the water a large deposit of the carbonate of zinc was formed, and the water was strongly impregnated with the chloride of zinc. Traces of lead were also detected in the water, derived probably from the lead impurities of the zinc. The links had decreased in weight 1.04 grains, and were heavily coated with the carbonates of zinc and iron.

From the foregoing described experiments, I am very much inclined to the opinion that both lead and galvanized iron pipes should be, as much as possible, discarded for service pipe in our city. Although the water, when constantly flowing through either of these pipes, may not become contaminated, yet when remaining in them a sufficient length of time there can be no question on the subject; and as it is very difficult to set exact bounds to the length of time required to produce these effects, their use must always be attended with more or less risk. To avoid all such risk, and allay all suspicion of this kind, perhaps no better material can be used than a good quality of iron pipe. The carbonate and oxide

of iron, at first produced by the water, will very soon combine with the clay and silex of silty matters of the water, and form a hard smooth lining which will both protect the iron from further oxidation and afford a channel for the water, wholly devoid of every thing that can in the least contaminate it in its passage. The outside may be protected by a coating of coal tar from the gas works, or water lime cement. Iron pipes are in many respects preferable to the more expensive ones of tin or tinned copper, on account of the difficulty of obtaining these metals pure when manufactured for such purposes. Wooden pipes might in many instances be advantageously used, or those made wholly of water lime. But there are objections to all of these which do not in the least militate against those of iron.

All of which is respectfully submitted.

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